PATENT
Attorney Docket No. 502469
Client Reference No. 03045

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Atul Kelkar et al.

Application No.: 10/731,742

Filed: December 9, 2003

For: METHOD AND SYSTEM TO PERFORM ENERGY-EXTRACTION BASED ACTIVE NOISE CONTROL

Art Unit: 2825

Examiner: Juan Carlos Ochoa

APPELLANTS' APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In support of the Appeal from the final rejection dated September 11, 2007 Appellants now submit their Appeal Brief required by 37 C.F.R. §41.37.

CERTIFICATE OF TRANSMISSION UNDER 37 CFR 1.8			
I hereby certify that this Appeal Brief and all accompanying documents are, on the date indicated below, ☒ being transmitted to the United States Patent and Trademark Office via the Electronic Filing System.			
Name (Print/Type)	A. Locke		
Signature	/A. Locke/	*Date*	March 10, 2008

(1) Real Party In Interest

The real parties in interest of the patent application that is the subject of this appeal are Iowa State University Research Foundation, Inc. and the United States of America as represented by The Administrator of the National Aeronautics and Space Administration (NASA), the assignees of the entire right, title and interest.

It is to be noted that this invention was made in part with Government support under Grant number NCC-1-01039 awarded by NASA and Grant Numbers 0196198 and 0301740 awarded by the NSF. The Government has rights in this invention.

(2) Related Appeals and Interferences

There are no appeals or interferences that are related to this appeal.

(3) Status of Claims

Claims 1 and 3-16 are currently pending in this application. Claims 1 and 10-15 stand rejected and are at issue herein and being appealed. Claims 3-7 are objected to as depending on rejected base claim 1 and claims 8, 9 and 16 are allowed.

The Appellant would like to note that the Advisory Action dated December 27, 2007 indicated that claims 3-7 stand rejected (see section 7), which contradicts their status after the Final Office Action dated September 11, 2007, which indicated that claims 3-7 were allowable, but objected to for depending on a rejected base claim in contravention to the Final Office Action dated September 11, 2007.

However, the Examiner was contacted with regard to his change in position with regard to claims 3-7 in the Advisory Action. Examiner Ochoa confirmed that claims 3-7 were improperly indicated as rejected in the Advisory Action and should have been indicated as objected to in the Advisory Action, such as in the Final Office Action dated September 11, 2007. As such, this appeal brief will be presented with the understanding that claims 3-7 are considered allowable by the Examiner, albeit objected to being dependent on a rejected base claim.

(4) Status of Amendments

All Amendments have been entered for purposes of appeal.

(5) Summary of Claimed Subject Matter

The present invention relates to energy extraction to actively control noise.

A concise explanation of the subject matter in each of the independent claims involved in the appeal is set forth below. Line number references noted below have been determined by counting only the lines of text of the cited paragraph as originally filed.

Claim 1

A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure. The method comprises the steps of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure (¶ [0030], lines 3-5); designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive (¶ [0030], lines 6-7); checking passivity of the compensated system (¶ [0031], line 1); and designing a passivity-based controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction(¶ [0031, lines 5-9; ¶ [0026], lines 7-8).

(6) Grounds of Rejection

The issue presented in this appeal is the following:

I. Does the combination of Kelkar and Joshi, entitled "Robust Passification And Control of Non-Passive Systems" (Kelkar hereinafter) taken in view of Son et al. entitled "Stabilization of Linear Systems Via Low-Order Dynamic Output Feedback: A Passification Approach" (Son hereinafter) and further in view of H.R. Pota and A.G. Kelkar, Modelling and Control of Acoustic Ducts (Pota hereinafter) teach or suggest the invention as claimed in claims 1 and 10-15 and present a *prima facie* case of obviousness for claims 1 and 10-15 under 35 U.S.C. § 103(a)?

<u>(7) Argument</u>

I. THE PROPOSED COMBINATION OF KELKAR IN VIEW OF SON IN FURTHER VIEW OF POTA FAILS TO MAKE OBVIOUS THE INVENTION AS CLAIMED IN CLAIMS 1 AND 10-15

There must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness. *In re Kahn*, 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir. 2006). See also *KSR v. Teleflex*, 82 USPQ2d at 1396 (citing to Federal Circuit statement with approval). In other words, the key to finding a *prima facie* case of obviousness under 35 U.S.C. § 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious. See MPEP 2143. While the prior art reference (or references when combined) need not teach or suggest all the claim limitations, Office personnel must explain why the difference(s) between the prior art and the claimed invention would have been obvious to one of ordinary skill in the art. MPEP 2143.

The proposed modification of Kelkar in view of Son and Pota fails to make obvious the invention as claimed in claims 1 and 10-15 as the combined references fail to teach or suggest the invention as claimed. As such, the Board is respectfully solicited to overturn the Examiner's rejection of claims 1 and 10-15 and indicate the allowability thereof as well as the claims held to be allowable, but objected to for depending on rejected claim 1, namely claims 3-7, which depend from claim 1.

Claim 1 relates to a method for designing a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure including, *inter alia*, "designing a passivity-based controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction."

The Examiner expressly states that "Kelkar and Son fails to teach designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction." Final Office Action dated September 11, 2007, at Pg. 4, ¶ 2, lines 4-6.

As such, the Examiner relied on Pota for teaching the step relating to designing a controller that extracts both acoustic energy <u>and</u> structural energy. However, Pota fails to teach or suggest a controller that extracts structural energy of the acoustic enclosure. As Pota

fails to teach such a controller, it also fails to teach the method of designing a controller that extracts structural energy from an acoustic enclosure.

More particularly, the Examiner indicates that Pota "discloses a passivity-based controller that extracts the structural energy (see claimed invention's 'structural energy' as 'A resonant controller [22] is part of this compensator. Resonant controllers have proved effective in damping vibrations in flexible structures.' in page 9, col. 1, 2nd paragraph, lines 14-16)." See Advisory Action dated December 27, 2007, Pg. 2, ¶ 5, lines 1-4 (quoting Pota)). However, such reliance on the quoted passage of Pota for teaching a step of designing a controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction of an acoustic duct is misplaced.

Pota only teaches using a speaker to reduce acoustic noise in an acoustic duct and does not teach any design of a controller regarding structural energy of the acoustic enclosure. Upon a thorough analysis of Pota, the experimental structures and theory of Pota only teach or suggest the use of microphones for sensing noise disturbances and loudspeakers that are driven by a controller to cancel noise propagation. (See Pota Pg. 5, Col. 1, ¶ 2, lines 1-3, 5-6, 7-9; Pg. 6, Col. 1, ¶ 2, lines 2-4; Pg. 6, Col. 2, ¶ 2, Lines 3-6, 12-15; Pg. 9, Col. 1, ¶ 3, lines 1-5). However, Pota fails to teach or suggest the use of a controller to extract structural energy of the acoustic duct. It also fails to teach or suggest sensors to sense structural vibrations or structural energy as well as actuators to cancel or counteract such vibrations. Thus, there is even less teaching or suggestion regarding designing such a controller for extracting the structural energy of the acoustic duct of Pota.

As illustrated in FIGS. 2 and 9 of Pota (reproduced below), the experimental ducts of Pota and particularly FIG. 9 which illustrates the experimental duct for testing the theories of Pota only includes a microphone and speakers. This is because "the aim [of the experimental setups in Pota] is to reduce the acoustic pressure, sensed by the microphone . . .in response to the noise." (Pota, Pg. 9, Col. 1, ¶ 3, lines 3-5).

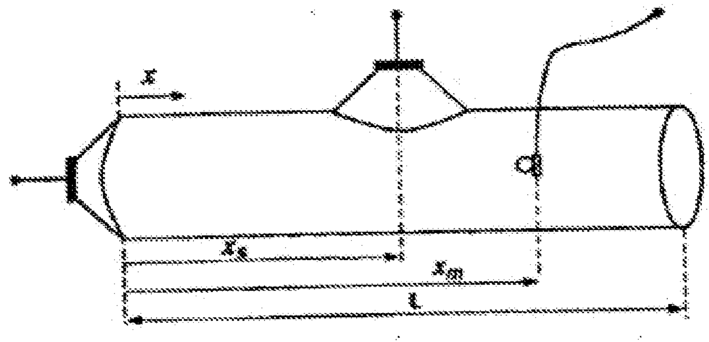


Fig. 2 Experimental duct at K-state

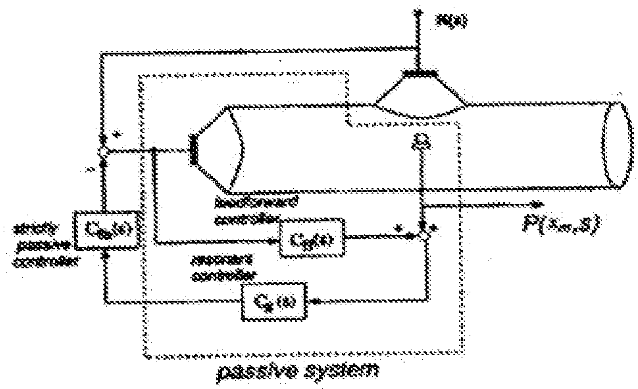
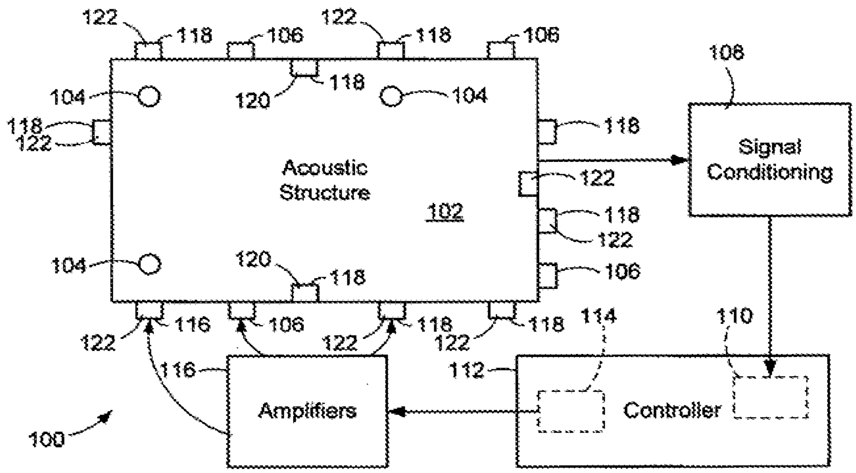


Fig. 9 Controlled experimental duct

In contrast, the structural device of the present invention, as illustrated in FIG. 1 reproduced below for convenience, includes both acoustic sensors 104 (e.g. microphones) and structural vibration sensors 106 (e.g. accelerometers) (both of which are illustrated schematically) for sensing the acoustic and structural energy, respectively. Also, the device in FIG. 1, includes acoustic signal generators 120 (e.g. loudspeakers) and piezo actuators 122 (both illustrated schematically) for dampening the acoustic energy (loud speaker 120) and structural energy (piezo actuators 122). As such, the method of the present invention can utilize the information gathered regarding both the acoustic energy and the structural energy of the acoustic enclosure and thus design a controller for controlling both the acoustic and structural energy.

FIG. 1



Because the experiments, experimental duct structures and underling theoretical analysis of Pota fail to relate to the structural energy of the duct, Pota entirely fails to teach or suggest the use of vibration sensors used to sense structural energy of the duct and actuators to dampen structural energy of the duct and design a controller for extracting structural energy of the acoustic duct. FIGS. 2 and 9 support this lack of teachings regarding any concern of the structural energy of the duct as these figures only include microphones and speakers and fail to include any vibration sensors or actuators. Because Pota fails to teach or suggest how to design a controller for extracting structural energy, Pota fails to teach or suggest designing a controller for extracting acoustic energy <u>and</u> structural energy.

The Appellants note that while Pota discusses that the compensator of its controller includes a resonant controller (see Pota Pg. 9, Col. 1, ¶ 2, lines 14-16) this resonant controller does not relate to controlling or dampening structural vibrations of the acoustic ducts of Pota. Instead as configured in FIG. 9 of Pota, the resonant controller provides feedback regarding the status of the microphone and feeds that information back to the strictly passive controller. As the microphone measures the acoustic energy of the system and not the structural energy of the duct, providing feedback regarding the acoustic energy received by the microphone does not teach extracting structural energy of the experimental acoustic duct. The resonant controller is not taught or disclosed as providing any feedback or control of structural vibrations of the duct.

The resonant controller is provided to counter act and dampen the frequency response between the microphone and loud speaker and to "push down" the "resonant peaks" at the

resonant frequencies of the duct produced by use of the load speaker. (See Pota, Pg. 9, paragraph bridging Cols. 1 and 2, lines 2-4; Pg. 5, Col. 2, ¶ 4, lines 4-10; Table 1). The use of this resonant controller provides robustness to the feedback controllers of the acoustic related control and does not provide any extraction of structural energy.

Further, Pota makes no teaching or suggestion as to how the resonant controller which forms part of the acoustic energy control feedback loop could be modified or implemented to extract structural energy from the acoustic duct. The Examiner fails to provide any such explanation as well.

While Pota cites to reference [22], namely: Pota, H.R., Reza Moheimani, S.O., and Smith, M., 1999, "Resonant controllers for flexible structures," in *Proceedings of IEEE International 38th Conference on Decision and Control*, pp. 631-636, Phoenix, Arizona, 7-10 December (herein "Pota 2"), the teachings of Pota 2 were not applied against the invention of claim 1. As such, the mere recitation that "[r]esonant controllers have proved effective in damping vibration in flexible structures" does not provide sufficient reasoning and "rational underpinnings" that one would be apply a resonant controller to extract the structural energy of an acoustic duct.

Further, the Examiner has not provided any rational explanation as to how it would have been obvious to apply the teachings of a resonant controller as applied to a flexible structure, such as presumably taught by Pota 2, to an acoustic duct. Thus, there is a further reason as to why no teaching or suggestion that such a modification could be implemented or how such a modification would be implemented.

Finally, pursuant to MPEP 706.02(j) "[w]here a reference is relied on to support a rejection, whether or not in a minor capacity, that reference should be positively included in the statement of the rejection. See *In re Hoch,* 428 F.2d 1341, 1342 n.3 166 USPQ 406, 407 n.3 (CCPA 1970)". As such, a purported reliance on the teachings of Pota 2 is not sufficient as it was not positively indicated as one of the references relied upon by the Examiner. The Examiner has always relied on Pota for making his case of obviousness.

As Pota fails to teach or suggest any controller for extracting structural energy of the acoustic duct, Pota further fails to teach or suggest any designing of such a controller. Thus, Pota fails to rectify this deficiency of the primary reference Kelkar, for which it was cited. Additionally, the Examiner provides no explanation as to how the differences between the combination of references and the claimed invention of claim 1 would be obvious.

As such, the combination of Kelkar, Son and Pota does not make obvious the invention as claimed in claim 1. The rejection of claim 1 based on this combination is legally deficient and cannot stand. The Board is respectfully solicited to overturn the obviousness rejection to claim 1.

As claims 10-15 depend from claim 1 and no additional references were cited against these claims, the obviousness rejection of these claims is improper for at least the above outlined reasons. The Board is further requested to overturn the obviousness rejection to claims 10-15.

II. CONCLUSION: CLAIMS 1, 3-7 AND 10-15 ARE IN CONDITION FOR ALLOWANCE

In view of the above, the Examiner has fully disregarded the fundamental principles of generating a *prima facie* case of obviousness with regard to the rejections based on a modification of Kelkar in view of Son and Pota. The combination fails to teach each and every limitation of the claimed invention and the Examiner has not provided any rational as to why the lack of the missing limitation would have been obvious.

The Appellants respectfully submit that claims 1, 3-7 and 10-15 are in condition for allowance. Consideration of this appeal, removal of the outstanding grounds of rejection and allowance of all rejected and objected to claims are respectfully solicited.

Respectfully submitted,

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Date: March 10, 2008

CLAIMS APPENDIX

1. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system; and

designing a passivity-based controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction.

2. (Canceled)

3. (Previously Presented) The method of claim 1 wherein the step of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure comprises the step of obtaining a mathematical model having the form according to the equation

$$E\dot{x}(t) = Ax(t) + Bu(t) + Df(t)$$

where A, B, D, and E are matrices given by

$$E = \begin{bmatrix} E_{11} & 0 \\ E_{21} & E_{22} \end{bmatrix} \qquad A = \begin{bmatrix} A_{11} & 0 \\ 0 & A_{22} \end{bmatrix}$$

$$B = \frac{1}{h\rho_0 S_1}\begin{bmatrix} B_{11} \\ 0 \end{bmatrix} \qquad D = \frac{1}{h\rho_0}\begin{bmatrix} D_{11} \\ 0 \end{bmatrix}$$

where $E_{11} = \mathrm{I}$ and $A_{11} = \mathrm{diag}(A_{11}^{nm})$ are square matrices of order p_1p_2, $E_{22} = \mathrm{I}$ and A_{22} $=\mathrm{diag}(A_{22}^{k_1k_2k_3})$ are square matrices of order $(l_1 + 1)(l_2 + 1)(l_3 + 1)$, B_{11} is a $p_1p_2\ x\ r$ matrix, D_{11} is a $p_1p_2\ x\ 1$ matrix where matrices E_{21}, A_{11}, A_{22}, B_{11}, and D_{11} are given by

$$E_{21} = -\frac{c_0^2 \rho_0}{V} \begin{bmatrix} 0 & 0 & \cdots 0 & 0 \\ 0 & \alpha_{00111} & \cdots 0 & \alpha_{001p_1p_2} \\ & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots 0 & 0 \\ 0 & \alpha_{l_1l_2l_311} & \cdots 0 & \alpha_{l_1l_2l_3p_1p_2} \end{bmatrix}$$

$$A_{11}^{nm} = \begin{bmatrix} 0 & 1 \\ -\omega_{nm}^2 & -2\zeta_{nm}\omega_{nm} \end{bmatrix}$$

$$A_{22}^{k_1k_2k_3} = \begin{bmatrix} 0 & 1 \\ -\omega_{k_1k_2k_3}^2 & -2\zeta_{k_1k_2k_3}\omega_{k_1k_2k_3} \end{bmatrix}$$

$$B_{11} = \begin{bmatrix} 0 & \cdots & 0 \\ \phi_{11}(x_{11}, y_{11}) & \cdots & \phi_{11}(x_{1r}, y_{1r}) \\ \cdots & \cdots & \cdots \\ 0 & \cdots & 0 \\ \phi_{p_1p_2}(x_{11}, y_{11}) & \cdots & \phi_{p_1p_2}(x_{1r}, y_{1r}) \end{bmatrix}$$

$$D_{11} = \begin{bmatrix} 0 \\ \gamma_{11} \\ \cdots \\ 0 \\ \gamma_{p_1p_2} \end{bmatrix}$$

where h is a thickness of the enclosure, ρ_0 is fluid density at equilibrium, S_1 is a boundary surface of the structure, c_0 is the sound speed, V is the volume of the enclosure, α 's are coupling coefficients describing the modal interaction between structural and acoustic modes, ω_{ij} denotes natural frequency related to ij-th mode for the structure, ω_{ijk} denotes the acoustical modal frequency for the ijk-th acoustic mode of the enclosure, ζ_{ij} is the damping of the ij-th structural mode shape, ζ_{ijk} is the damping of the ijk-th acoustical mode shape,

ϕ_{ij} is the ij-th mode shape of the enclosure structure, and γ_{ij} in matrix D_{11} indicate non-zero coefficients for the direct transmission terms which are functions of modal parameters.

4. (Previously Presented) The method of claim 1 wherein the step of designing a passivity-based controller includes designing a controller having a transfer function G(s) wherein

$$G(s) = Js^2 \sum_{k_1=0}^{l_1} \sum_{k_2=0}^{l_2} \sum_{k_3=0}^{l_3} \frac{\psi_{k_1k_2k_3}(x,y,z)}{s^2 + 2\zeta_{k_1k_2k_3}\omega_{k_1k_2k_3}s + \omega^2_{k_1k_2k_3}} [\sum_{n=1}^{p_1} \sum_{m=1}^{p_2} \frac{\alpha_{k_1k_2k_3nm}\phi_{nm}(x_{11}, y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega^2_{nm}}]$$

where $J = \frac{c_0^2 \rho_0}{Vh\rho_p S_1}$, h is a thickness of the enclosure, ρ_0 is fluid density at equilibrium, S_1 is a boundary surface of the structure, c_0 is the sound speed, ρ_p is the density of the plate, $\psi_{k_1k_2k_3}(x,y,z)$ are normal modes of a non-homogeneous wave equation, $\omega_{k_1k_2k_3} = c_0\sqrt{\xi^2_{k_1} + \xi^2_{k_2} + \xi^2_{k_3}}$ with ξ_{k_1}, ξ_{k2}, and ξ_{k3} being modal coordinates, ζ_{ijk} is the damping of the ijk-th acoustical mode shape, α's are coupling coefficients describing the modal interaction between structural and acoustic modes, and ζ_{ij} is the damping of the ij-th structural mode shape.

5. (Previously Presented) The method of claim 1 wherein the acoustic enclosure has a soft boundary and the step of designing a passivity-based controller includes designing a controller having a transfer function $G_{sb}(s)$ wherein

$$G_{sb}(s) = \sum_{i=1}^{l} \frac{\rho_0 s^2 c_0^2}{h\rho_p S_1} \cdot \frac{\Psi_i(r_0)}{s^2 + \rho_0 c_0^2 s D_{ii}(s) + c_0^2 \beta_{ii}} \cdot [\sum_{n=1}^{p_1} \sum_{m=1}^{p_2} \frac{\eta_{inm}\phi_{nm}(x_{11}, y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega^2_{nm}}]$$

where Ψ_i denotes the eigenmode function for the acoustic pressure expression obtained using the assumed modes method, η_{inm} is the volume integral term consisting of integrand which is product of structural-acoustic eigenfunctions, ζ_{ij} is the damping of the ij-th structural mode shape, ρ_0 is fluid density at equilibrium, c_0 is the sound speed, S_1 is a boundary surface of the structure, h is a thickness of the enclosure, ρ_p is the density of the plate, ϕ_{ij} is the ij-th mode shape of the enclosure structure, and

$D_{ij}(s) = \int_S \frac{\Psi_j(s)\Psi_i(s)}{Z(r,s)} dS$, $\beta_{ij}(s) = \int_V \nabla\Psi_j(r)\nabla\Psi_i(r)dV$ where Z is the impedance.

6. (Previously Presented) The method of claim 1 wherein the step of designing compensation includes the step of designing a series passifier $C_s(s)$ according to $C_s(s) \approx \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ u' = C_c x_c + D_c u \end{cases}$ wherein *Ac*, *Bc*, *Cc*, and *Dc* are determined according to the steps comprising:

solving the equation $\begin{bmatrix} A^{**} & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ \hat{D}^T B^T - CX - D\hat{C} & \hat{B}^T - C & D^{**} \end{bmatrix} < 0$ to obtain $X, Y, \hat{A}, \hat{B}, \hat{C},$ and $\hat{D}$;

constructing matrices *M*, *N*, and *P* such that

$P\Pi_1 = \Pi_2$ and $\Pi_1^T \Pi_2 = \begin{bmatrix} X & I \\ I & Y \end{bmatrix}$ where $XY + MN^T = I$, $\Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix}$, $\Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}$, $P = \begin{bmatrix} Y & N \\ N^T * & \end{bmatrix}$; and

solving the equations $\hat{A} = YAX + YBC_c M^T + NA_c M^T$, $\hat{B} = YBD_c + NB_c$, $\hat{C} = C_c M^T$, and $\hat{D} = D_c$ in reverse order to obtain *Ac*, *Bc*, *Cc*, and *Dc*.

7. (Previously Presented) The method of claim 1 wherein the step of designing compensation comprises the step of designing a feedforward compensator $C_{ff}(s)$ according to $C_{ff}(s) \approx \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ y_2 = C_c x_c + D_c u \end{cases}$ wherein *Ac*, *Bc*, *Cc*, and *Dc* are determined according to the steps comprising:

solving the equation $\begin{bmatrix} AX + XA^T & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ B^T - CX - \hat{C} & B^T Y + \hat{B}^T - C & D^{\perp} \end{bmatrix} < 0$ where

$D^{\perp} = -(D + D^T + \hat{D} + \hat{D}^T)$ to obtain $X, Y, \hat{A}, \hat{B}, \hat{C},$ and $\hat{D}$;

constructing matrices M, N, and P such that

$$P\Pi_1 = \Pi_2 \text{ and } \Pi_2^T \tilde{A} \Pi_1 = \begin{bmatrix} AX & A \\ YAX + NA_c M^T & YA \end{bmatrix} \text{ where } XY + MN^T = I,$$

$\Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix}$, $\Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}$, $P = \begin{bmatrix} Y & N \\ N^T * & \end{bmatrix}$; and

solving the equations $\hat{A} = YAX + NA_c M^T$, $\hat{B} = NB_c$, $\hat{C} = C_c M^T$, and $\hat{D} = D_c$ in reverse order to obtain *Ac*, *Bc, Cc*, and *Dc*.

8. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the step of performing sensor blending if there are redundant sensors.

9. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the step of performing control allocation if there are redundant actuators.

10. (Original) The method of claim 1 wherein the step of designing compensation to render the mathematical model passive comprises the steps of:

determining if a feedforward compensation will passify the system;

if a feedforward compensation will not passify the system:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation.

11. (Original) The method of claim 10 wherein the step of designing a passivity-based controller comprises the step of designing one of a dissipative linear-quadratic-Gaussian (LQG) type positive-real controller and a dissipative constant gain positive-real controller.

12. (Original) The method of claim 10 wherein the step of rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation comprises the step of rendering the compensated system positive-real by at least one of series compensation, feedback compensation, hybrid compensation, and sensor-blending and control allocation.

13. (Previously Presented) The method of claim 1 further comprising the step of redesigning the compensation if the passivity is not preserved.

14. (Previously Presented) The method of claim 1 further comprising the step of performing numerical simulations of the controller in the presence of a simulated broadband disturbance input.

15. (Original) The method of claim 14 further comprising the step of redesigning the controller if the closed-loop response is not satisfactory.

16. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the steps of:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by one of sensor-blending and control allocation.

EVIDENCE APPENDIX

None

RELATED PROCEEDINGS APPENDIX

None.